Seasonal Variation of Precipitation Properties Associated with Monsoon over Palau

Hisayuki Kubota, Ryuichi Shirooka, Tomoki Ushiyama, Takashi Chuda, Suginori Iwasaki and Kensuke Takeuchi

Institute of Observational Research for Global Change

Japan Agency for Marine-Earth Science and Technology (IORGC, JAMSTEC)

2-15 Natsushima-cho, Yokosuka, Kanagawa, JAPAN 237-0061, email: kubota@jamstec.go.jp

Abstract

Seasonal variation of precipitation properties associated with monsoon wind direction is investigated focusing on data of Peleliu Island at Republic of Palau of Western Pacific from Jun. 2001 to Apr. 2002. Westerly wind monsoon period starts at 18 May. 2001 and easterly wind monsoon starts at 26 Nov. which dates are affected by intraseasonal oscillations. During westerly wind monsoon period, westerly winds are prevailed and their intensities are correlated with cloud amount. Diurnal variation of precipitation is also prevailed with nocturnal maximum during convective active phase. Precipitation has strong intensity with short duration. On the other hand, during easterly wind monsoon period, zonal winds are weak correlated with cloud amount. The properties of precipitations have weak intensity with long duration compared from westerly monsoon. When dry air comes from subtropics, convection is suppressed. However averaged rainfall rate is same as westerly monsoon period.

Keywords: western Pacific, precipitation, monsoon

1. Introduction

Seasonal variation over western Pacific region is closely related to the Asian monsoon. Western North Pacific region is one of the distinct monsoon regions (Murakami and Matsumoto, 1994). Over continental area from India to Indochina Peninsula, apparent wet and dry season appeared. When rainy season does start is critical for local agriculture and water resource and so on. Therefore seasonal march of monsoon was discussed well for the rainy season. The period of wet and dry season was determined by many researches using satellite OLR (Outgoing Long wave Radiation) data which is an index of convective activity and rainfall data (Tanaka, 1992; Lau and Yang, 1997; Wang and LinHo, 2002).

The term "monsoon" has been generally defined by a seasonal variation of surface wind (Ramage, 1971). Western Pacific region has been recognized that low-level wind changes its direction apparently from easterly to westerly during northern hemisphere summer monsoon (Matsumoto, 1992). Institute of Observational Research for Global Change has been conducted the observational project PALAU (Pacific Area Long-term Atmospheric observation for the Understanding of climate change) over Peleliu Island (7.05°N, 134.27 °E) of Republic of Palau (Fig. 1). In this study we define the monsoon season by using low-level zonal wind at Koror (7.33°N, 134.48°E) (Fig. 1) and focus on the seasonal variation of precipitation properties over western Pacific associated with monsoon wind direction using Peleliu station data which is expected to be less affected from large island.

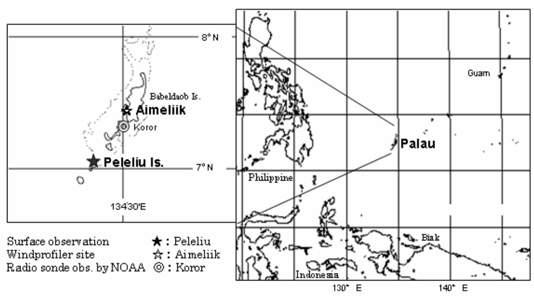

Fig. 1: Maps of western Pacific region. Left side is the enlarged map around Palau.

2. Data

We use precipitation and equivalent cloud amount data observed at Peleliu station from 28 June 2001 to 30 April 2002. Equivalent cloud amount is calculated by the frequency of cloud base measurement of Ceilometer within every hour. These values are assumed to be useful index for understanding the activity of cloud over Palau. Upper air sounding is used which is carried out by Koror National Weather Service (NWS) from 1973 to 2003. Special Sensor Microwave Imager (SSM/I) precipitable data are used of 1°x 1° averaged data at the same region of Palau.

3. Monsoon season

We defined the monsoon season over Palau using zonal wind at 850 hPa height. We used a threshold of five days running mean 5 m/s westerly wind to define the westerly wind monsoon season. Figure 2 shows the time series of zonal wind and westerly wind monsoon period at Palau. Westerly wind monsoon onset appears around May to July. Withdrawal dates appear around September to December. The dates are affected by the phase of intraseasonal oscillation. We can see that westerly wind does not always blow even during westerly wind monsoon season.

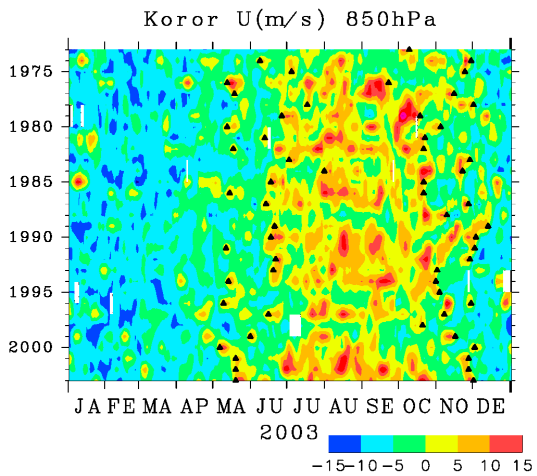

Fig. 2: Seasonal and annual variation of daily averaged zonal wind at 850 hPa at Koror from 1973 to 2003. The intensities of zonal wind are indicated by colors. Westerly wind monsoon onset and withdrawal dates are plotted by triangles

4. Seasonal variability over Palau

In this section we focus on the seasonal variability observed at Peleliu Island station by dividing westerly wind monsoon from easterly wind monsoon. Peleliu Island is a very small island and its length is less than 10 km. The effect of land-sea breeze circulation and daytime convection due solar heating over land surface is small. Therefore we can assume observation data at Peleliu Island is representative as over an open ocean.

4.1 Zonal wind and cloud amount

Figure 3 shows the time series of equivalent cloud amount and Koror 850 hPa zonal wind from 28 June 2001 to 30 June 2002. Westerly wind monsoon period continued until 25 November 2001 and the next westerly wind monsoon onset is 18 May 2002. During westerly wind phase equivalent cloud amount and zonal wind are well correlated and correlation coefficient is 0.71. When westerly wind is intensified, equivalent cloud amount increases, which indicate that convective activity is intensified over Palau. On the other hand, during easterly wind monsoon equivalent cloud amount does not decrease as zonal wind direction changes to easterlies. There is no correlation between equivalent cloud amount and zonal wind during easterly wind monsoon. After westerly wind monsoon has finished northeasterly trade wind is prevailed over Palau.

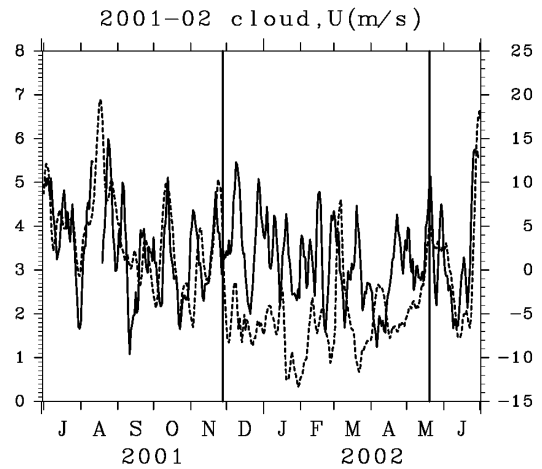

Fig. 3: The time series of equivalent cloud amount (solid line) and Koror 850 hPa zonal wind (dotted line) from 28 June 2001 to 30 June 2002.

4.2 Diurnal variation of precipitation

We compared the diurnal variation of precipitation during westerly wind monsoon from easterly wind. In this study we also divided the analyses period of active phase of convection from inactive phase using equivalent cloud amount data. Threshold of 5 day running mean equivalent cloud amount more than 4 is active phase and less than 3 is inactive phase (see Fig. 3). Diurnal variation of precipitation has nocturnal maximum during active phase on westerly wind phase (Fig. 4a). On the other hand, in inactive phase diurnal variation is weak and has small afternoon maximum (not shown). The feature of diurnal variation of precipitation during westerly wind monsoon is consistent with the previous work over equatorial western Pacific (Sui et al., 1997; Chen and Houze, 1997; Kubota and Nitta, 2001). However it was not clear during easterly wind phase (Fig. 4b).

(a) (b)

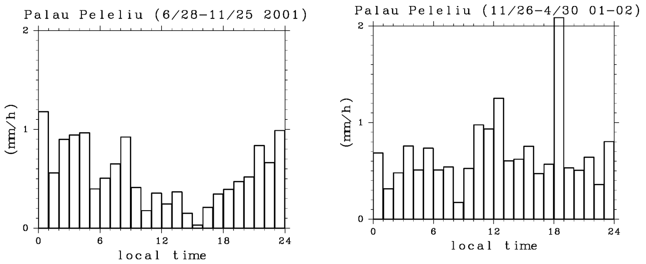

Fig. 4: Diurnal variation of precipitation averaged in active phase during westerly wind monsoon (a) and easterly wind monsoon (b). Units are mm/h

4.3 Duration and intensity of rain event

Diurnal variation of precipitation was obscure during easterly wind monsoon. We examine the precipitation properties further what make this difference during easterly wind phase from westerly wind phase. We defined rain event as continuous rain without 3 hours intermittence of less than 0.1 mm/h using hourly precipitation data at Peleliu Island. Figure 5 shows the frequencies and intensities of rain event divided westerly wind phase from easterly wind. Rain event frequency of more than 13 hours during easterly wind phase reaches more than twice as westerly wind. This means that long rain event is evident during easterly wind monsoon compared from westerly wind. Almost all duration of rain event show that the intensity of rain event is strong during westerly wind monsoon. Tagami (1990) suggested that diurnal variation of precipitation is apparent at the case of rain event of short duration within 11 hours and strong intensity over Japan. Therefore weak diurnal variation during easterly wind monsoon comes from long duration and weak intensity of rain event.

5. Summary and discussions

We are conducted the observational project PALAU over Peleliu Island (7.05°N, 134.27 °E) of Republic of Palau. Precipitation and equivalent cloud amount observed at Peleliu Island station were used from 28 June 2001 to 30 April 2002. We defined the monsoon season using five days running mean 850 hPa zonal wind sounding data over Palau as the period more than 5 m/s. Westerly wind monsoon onset appears around May to July. Withdrawal dates appear around September to December. The onset and withdrawal date of westerly wind monsoon depends on the phase of intraseasonal oscillation.

The averaged characteristics of precipitation properties and others during westerly wind monsoon and easterly wind monsoon are listed in Table 1. The values of zonal wind at 850 hPa height are nearly same with opposite direction. The difference of precipitation and equivalent cloud amount compared westerly from easterly is within 10 %. Precipitation and cloud amount does not decrease even during easterly wind phase. Precipitable water has difference at westerly wind monsoon from easterly wind. This is due to the dry air comes from subtropical region during easterly wind phase (not shown). CAPE also has a difference between westerly and easterly. Diurnal variation of precipitation has nocturnal maximum during active phase on westerly wind phase. However it was not clear during easterly wind phase. The intensity of precipitation was strong and duration was short during westerly wind phase. On the other hand, weak intensity and long duration was observed during easterly wind monsoon. During westerly wind phase, Palau locates southern region of ITCZ. And during easterly wind phase, ITCZ moves south of Palau and subtropics dry air propagates around Palau. Therefore the difference of precipitation properties may be related with the difference of large-scale circulation.

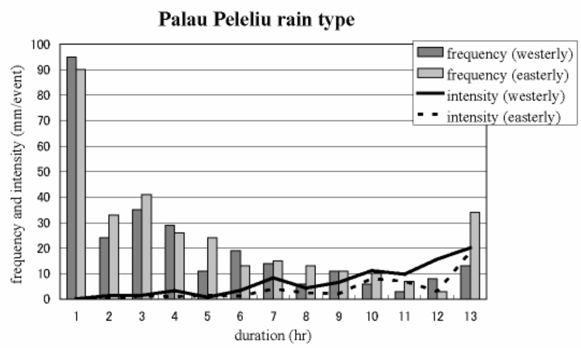

Fig. 5: Frequencies (boxes) and intensities (lines) of rain event distributed every duration of rain event. Westerly wind phase is dark boxes and solid line. Easterly wind phase is light boxes and dotted line. Unit of frequency is numbers and intensity is mm/ event. The abscissa is duration (hours) and 13 represents more than 13 hours

	6/28-11/25	11/26-4/30
zonal wind	3.7m/s	-3.4m/s
precipitation	8.8mm/day	8.8mm/day
cloud amount	35.6%	32.5%
Precipitable water	55.0mm	47.8mm
CAPE	2824(m/s)²	1879(m/s)²
diurnal variation of precipitation	Nocturnal maximum (active phase)	Not clear
intensity/ duration of precipitation	strong/ short	weak/ long

Table 1 Comparison between westerly wind monsoon and easterly wind monsoon.

Acknowledgements

SSM/I data was obtained from the Remote Sensing System. The GFD-DENNOU library was used for the drawing of figures.

References

Chen, S. S. and R. A. Houze, Jr., 1997: Diurnal variation and life-cycle of deep convective systems over the tropical Pacific warm pool, *Q. J. R. Meteorol. Soc.*, **123**, 357-388.

Kubota, H. and T. Nitta, 2001: Diurnal variations of tropical convection observed during the TOGA-COARE, *J. Meteor. Soc. Japan*, **79**, 815-830.

Lau, K. -M. and S. Yang, 1997: Climatology and interannual variability of the Southeast Asian summer monsoon. *Adv. Atmos. Sci.*, **14**, 141-162.

Matsumoto, J., 1992: The seasonal changes in Asian and Australian monsoon regions, *J. Meteor. Soc. Japan*, **70**, 257-273.

Murakami, T. and J. Matsumoto, 1994: Summer monsoon over the Asian continent and western North Pacific. *J. Meteor. Soc. Japan*, **72**, 719-745.

Ramage, C. S., 1971: *Monsoon Meteorology*, Academic Press, 296pp.

Sui, C.-H, K.-M. Lau, Y. N. Takayabu and D. A. Short, 1997: Diurnal variations in tropical oceanic cumulus convection during TOGA COARE, J. Atmos. Sci., 54, 639-655.

Tagami, Y., 1990: Diurnal variation of precipitation and thunderstorm frequency in the Japanese Islands, *Geographical Review of Japan*, **63 A-7**, 407-430 (in Japanese).

Tanaka, M., 1992: Intraseasonal oscillation and the onset and retreat dates of the summer monsoon over East, Southeast Asia and the Western Pacific region using GMS high cloud amount data. *J. Meteor. Soc. Japan*, **70**, 613-629.

Wang, B. and LinHo, 2002: Rainy seasons of the Asian-Pacific monsoon. *J. Climate*, **10**, 1071-1085.